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TETRAPLOID *TARAXACUM KOK-SAGHYZ*

III. ACHENE WEIGHT, FLOWERING, AND PLANT DEVELOPMENT[1]

BY M. W. BANNAN[2]

Abstract

The ultimate size of diploid or tetraploid kok-saghyz plants, when grown in pots or at wide spacings in the field, was not determined primarily by the weight of the achenes from which they originated. Conversely large or small tetraploids when crossed among themselves did not produce achenes reflecting the differences in plant size. Tetraploids differed from diploids in possessing larger organs, but increase in size was more or less counteracted by reduction in numbers. This was especially true as regards flowering. Tetraploids were notably deficient in the production of inflorescences during the first year, and since they were correspondingly freed from the inhibiting effects of flower and seed development on root enlargement, the root size of the vegetating tetraploids tended to surpass that of the more floriferous diploids, unless the latter were disbudded. On the whole first-year plants with the broadest and leafiest rosettes and few or no capitula developed the biggest roots. An association of such characteristics is probably the best criterion for the selection of large-rooted plants. When large root size is desired it would seem advisable to avoid pregermination treatments that hasten maturation and stimulate flowering.

Introduction

In previous articles (1 and 2) the production of tetraploid kok-saghyz by the use of colchicine, and the characteristics of parental and F_1 tetraploids were described. The present paper deals with investigations on the weight of achenes and size of plants, and also with the correlation of the various morphological characters from the standpoint of their usefulness in the selection of desirable plants and their bearing on the agronomic possibilities of tetraploids.

Methods

To supplement the data on F_1 plants acquired during 1945, further plantings, both of the same and additional crosses, were made in 1946 from seed then two years old. The achenes, which had been stored at room temperature, were not chilled prior to germination. In March 1946 they were weighed, placed on moist filter paper in Petri dishes, and when the radicles protruded, the seedlings were set out singly in sterile soil in $2\frac{1}{2}$ in. pots. Because inclement

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Contribution from the Department of Botany, University of Toronto, Toronto, Ont., with financial assistance from the National Research Council of Canada and the University of Toronto.

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weather delayed the preparation and decontamination of the garden plot, the plants remained in the small pots until mid-June. As a consequence the seedlings were forced into a premature maturation, and many began to flower. When finally transplanted in the plot, at foot spacings in rows 18 in. apart, vegetative growth was resumed and enlargement of the rosettes proceeded rapidly. After the attainment of maximum size in late August and early September, many of the plants flowered again, but head production was not heavy. The plants were harvested in mid-October. Although the roots were dug with care, there was unavoidable breakage of the distal portions of the root systems. By mutilation of the roots of potted plants to make them comparable with roots removed from the plot, it was estimated that 15 to 20% of the roots of field plants was left in the ground. That loss in weight should be taken into account if field and potted plants are compared. After the plants were removed from the ground the leaves were twisted off, but the crowns were left intact so that any plant selected could be repotted for possible future use. The root weights presented in this paper thus include the roots and crowns, as illustrated in Fig. 6.

Parallel series of diploids and tetraploids, grown from selected large and small achenes, were also established. The diploid seed, harvested in 1945, was obtained from Dr. L. Truscott of the Ontario Agricultural College, Guelph, Ont. The tetraploid seed was a general collection from open-pollinated plants of various F_1 populations also grown in 1945. The seed was stored over winter at room temperature, and was not given any pregermination chilling. From both $2n$ and $4n$ seed collections, the longest and shortest plump achenes were selected. Only well-filled achenes were chosen, all thin or flat specimens being discarded regardless of length. Four lots of large and small, diploid and tetraploid achenes were germinated in mid-March (Series *A*), and another four lots (Series *B*) were started two weeks later. The seedlings were set out singly in $2\frac{1}{2}$ in. pots and later transferred to 8 in. pots. The plants of Series *A* were moved outside in mid-June, and the pots sunk in the greenhouse yard, while those of Series *B* were kept in the greenhouse throughout the summer. The plants outside were given water as required, those in the greenhouse were watered every day. The greenhouse plants, exposed to very high temperatures during July and August, grew little during the later part of the summer and produced much smaller roots than the plants outside. The roots of all plants were harvested in early October.

Weight of Achenes and Plant Development

Data on weight of achenes and size of the resulting plants are presented in Tables I and II for the F_1 progenies of specific crosses grown in 1945 and 1946, and in Table III for F_2 plants derived from large or small achenes selected from a general seed collection. In the case of the 1946 plantings in the garden plot (Table I) there appeared to be a tendency for the F_1 progenies derived from large achenes to have the biggest roots, as illustrated by the cross 578 ×

TABLE I

TETRAPLOID F_1 PROGENIES GROWN IN THE GARDEN PLOT (1946)

Cross	No. of plants	Av. weight of achenes, mgm.	Av. no. of green leaves at maximum	Av. diam. of rosette at max., in.	Av. fresh weight of roots, gm.
578 × 583	27	0.93	52.0	12.7	41.5
629 × 578	18	0.92	49.0	12.5	26.1
578 × 603	19	0.89	45.6	13.7	31.6
31 × 145	15	0.86	47.3	11.3	32.6
71 × 107	30	0.80	32.4	10.0	30.0
31 × 314	18	0.79	46.0	11.6	22.8
257 × 107	33	0.78	46.3	12.0	33.4
17 × 257	6	0.77	25.5	7.4	13.8
578 × 629	27	0.74	72.6	13.8	35.1
107 × 17	15	0.74	33.6	9.2	27.6
621 × 436	18	0.71	30.5	9.7	15.9
612 × 631	14	0.69	31.5	10.1	19.0
107 × 71	7	0.68	32.2	9.9	39.0
31 × 21 (*A*)	9	0.68	25.0	7.3	17.0
625 × 578	11	0.68	35.4	9.7	16.0
625 × 634	11	0.66	35.2	12.0	16.5
612 × 578	17	0.64	66.1	12.9	23.3
31 × 21 (*B*)	19	0.62	28.9	7.4	17.1
31 × 223	12	0.54	50.0	12.2	25.2
31 × 195	18	0.49	36.5	10.9	17.4
217 × 270	15	0.48	44.2	15.0	29.7
31 × 17	15	0.45	28.9	9.3	16.3

TABLE II

TETRAPLOID F_1 PROGENIES GROWN IN 8-IN. POTS (1945 AND 1946)

Cross	No. of plants	Av. weight of achenes, mgm.	Av. no. of heads	Av. no. of leaves at max.	Av. diam. of rosette at max., in.	Av. fresh weight of roots, gm.
578 × 562 (1945)	27	0.98	12.8	33.5	9.7	20.1
629 × 619 (1945)	4	0.86	18.5	31.8	10.5	11.9
21 × 107 (1945)	17	0.76	4.5	23.3	7.9	17.9
21 × 296 (1945)	29	0.75	17.1	27.3	9.2	15.5
296 × 21 (1945)	8	—	11.9	28.3	9.0	10.0
71 × 86 (1946)	17	0.75	0	31.9	12.7	29.5
71 × 86 (1945)	16	0.74	14.4	26.6	8.8	20.1
21 × 31 (1945)	19	0.71	19.3	27.8	9.3	12.6
86 × 47 (1946)	22	0.70	0.3	30.6	11.7	18.7
86 × 54 (1946)	8	0.63	0	40.0	16.0	35.0
31 × 21 (1945)	26	0.61	23.8	30.8	9.6	16.7
619 × 629 (1945)	16	0.58	12.5	26.7	8.8	16.7
31 × 17 (1945)	33	0.57	7.4	24.4	8.0	21.0
20 × 265 (1945)	15	0.57	13.0	23.3	8.0	13.6
71 × 17 (1945)	29	0.55	8.4	23.8	8.4	18.3
86 × 71 (1946)	17	0.53	0.2	31.5	13.4	30.5
86 × 71 (1945)	28	0.52	10.2	32.1	9.4	23.5
86 × 70 (1946)	41	0.52	0.4	32.3	11.9	21.5
70 × 86 (1945)	14	—	12.7	31.2	9.6	23.2
31 × 257 (1945)	17	0.51	11.8	34.9	10.1	24.1
86 × 31 (1946)	40	0.44	0.2	28.7	11.2	23.5
31 × 86 (1945)	38	—	9.1	38.8	9.9	24.3

TABLE III

COMPARISON OF DIPLOIDS AND TETRAPLOIDS GROWN FROM LARGE AND SMALL ACHENES

Series	Type	No. of plants	Av. weight of achenes, mgm.	Av. no. of heads	Av. no. green leaves at max.	Av. diam. rosette at max., in.	Av. fresh root weight, gm.
A (moved outside in June)	2*n*	26	0.54	31.3	98.3	11.9	26.6
		32	0.33	42.9	97.3	12.6	27.1
	4*n*	39	0.91	4.2	38.7	11.9	34.8
		40	0.57	3.5	35.3	11.5	27.8
B (kept in greenhouse all summer)	2*n*	39	0.50	17.3	63.0	12.0	9.4
		42	0.34	32.6	60.5	11.1	10.7
	4*n*	39	0.90	2.8	34.1	11.4	17.5
		50	0.62	1.7	32.4	12.0	15.2

583. However, an examination of the data reveals many outstanding exceptions, as for instance the F_1 of 107 × 71 where the achenes were of moderate size and the roots very large. In Table II, which records the results of the plantings of different F_1 progenies in pots, no parallel between achene weight and plant size is apparent. In fact, the trend here was in the opposite direction, some of the largest plants developing from small achenes. Finally, in the parallel Series *A* and *B* grown from selected large or small achenes, no constant differences in ultimate size of rosettes or of roots were discovered (Table III). Actually the diploids grown from small seed had slightly larger roots, whereas the reverse was true in the tetraploids.

The data in Tables I and II indicate that such morphological characters as number of leaves, diameter of the rosette, amount of flowering, and size of the roots are to some extent heritable, though they are also, of course, profoundly modified by the environment. For instance, the F_1 progenies of 31 × 21, whether planted in pots or in the garden plot, produced roots below average size, the average weights in three plantings being 17.0, 17.1, and 16.7 gm. In contrast the F_1 progenies of plants numbered 86, 107, and 587 developed roots much exceeding average size. The wide differences in number of leaves at the maximum development of the rosette in July and August, when the averages of the different families ranged from 25.5 to 72.6, and the similar differences in the diameter of the rosette are probably also to be interpreted as indicative of the operation of an inheritance mechanism. Similarly the weight of the achenes centered about different values for the various seed parents, although varying with the pollen parent. In some instances large achene size was associated with vigorous plant growth. This was true in the progeny of Plant 578, and to a lesser extent in the progeny of 107. On the other hand the achenes in most of the crosses involving Plant 86 were small, but the F_1 progeny were large. Evidently there may be various assortments of the size factors for the different morphological characters, and large size of achenes is not necessarily associated with bigness of plant.

Records were kept of the rosette characteristics of plants in Series *A* and *B* to determine whether achene weight had an influence on rate of growth. In the diploids the rosettes of seedlings derived from large achenes were slightly bigger than those of seedlings grown from small seed, the average differences in numbers of leaves and diameter of the rosette at 20 to 30 days being 10 to 20%. As the plants matured these differences disappeared. However, in close plantings it might be expected that the derivatives of large achenes would be at an advantage because of their more rapid early growth. In the tetraploids no constant differences in the rosettes were observed between the derivatives of large or small achenes during early growth, though at maturity the plants grown from large achenes had slightly bigger roots.

Size of Plants and Weight of Achenes Produced

After the roots of the F_1 tetraploids were weighed in the autumn of 1945 the largest and smallest were repotted, and when flowering ensued in the spring of 1946 the large and small plants were crossed among themselves. The average weight of the achenes produced in 80 cross-pollinations between large plants, whose roots weighed 36 to 79 gm. at the end of the first season's growth, was 0.65 mgm. The weight of achenes resulting from crossings between small plants, with roots of 8.5 to 10 gm., was the same, namely, 0.65 mgm. The achene weight fluctuated widely in different plants, the average weights in various crosses tending to cluster about different values specific for each seed parent, but these differences were not related to plant stature. Similar fluctuations were noted in average achene weight in both large and small plants.

Correlation of Morphological Characteristics

In general, plants with the widest and leafiest rosettes produced the biggest roots (Table IV), the trends in the 1946 plantings repeating those

TABLE IV

RELATIONSHIPS BETWEEN FRESH ROOT WEIGHT, HEAD PRODUCTION, NUMBER OF LEAVES, AND SIZE OF THE ROSETTE IN FIRST-YEAR DIPLOIDS AND TETRAPLOIDS

Type	Root weight, gm.	No. of plants	Av. no. of heads	Av. no. of leaves at max.	Av. diam. of rosette at max., in.
2*n*	To 19.9	13	52.2	91.7	11.2
	20–29.9	25	38.2	93.7	11.8
	30–39.9	16	29.3	113.3	13.3
	40–49.9	4	7.0	106.8	13.8
4*n*	To 19.9	16	6.3	31.8	9.6
	20–29.9	25	6.4	37.1	11.8
	30–39.9	16	2.4	36.8	12.2
	40–49.9	16	0	50.5	13.4
	Over 50	6	0	48.5	12.8

observed in 1945 and reported in a previous paper (2). However, individuals were highly variable and some deviated widely from the general trend (Figs. 1 and 2). For instance, among the diploids illustrated in Fig. 1, the plant with

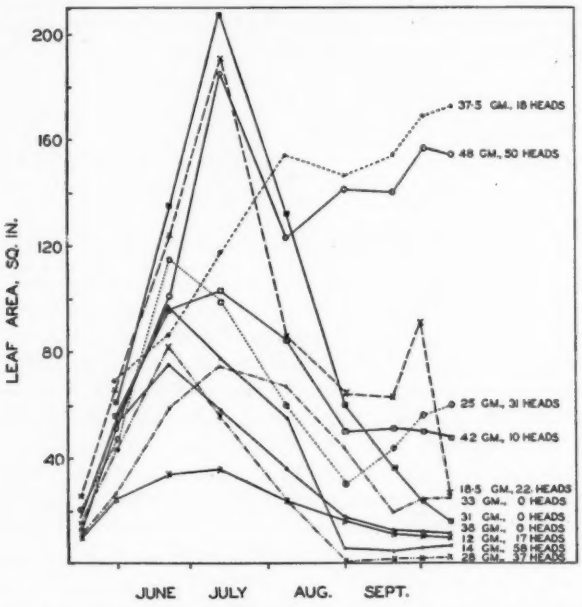

FIG. 1. *Seasonal alterations in leaf area in representative first-year diploids grown from large achenes, Series A. Root weight and head production of each plant are indicated to the right.*

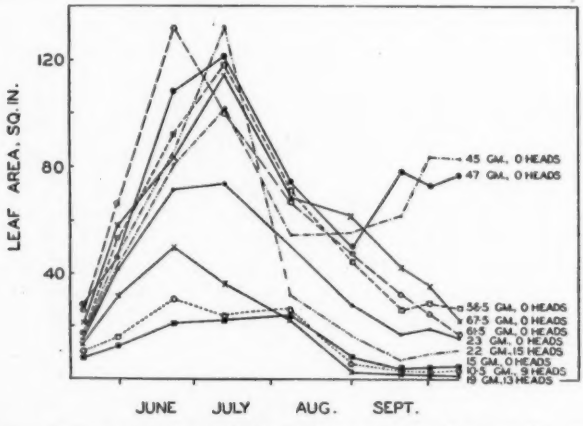

FIG. 2. *Seasonal alterations in leaf area in representative first-year F_2 tetraploids grown from large achenes, Series A.*

the greatest leaf area (208 sq. in.) developed a root weighing 31 gm., whereas other individuals with less than half that leaf area (75 and 77 sq. in.) produced slightly larger roots weighing 33 and 38 gm. It might be noted that all three plants were alike in their lack of flowering.

The seasonal alterations in number and width of leaves are illustrated in Fig. 3 for first-year diploids and tetraploids of Series *A*. The number of

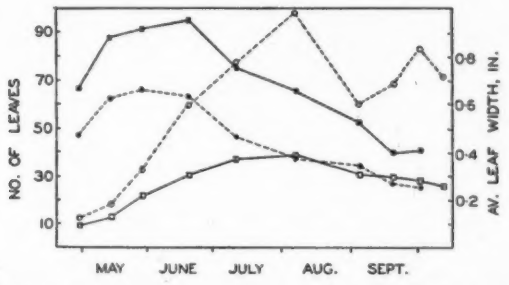

FIG. 3. *Seasonal trends in number of leaves and leaf width in first-year diploids and F_2 tetraploids, grown from large achenes, Series A. The leaf width indicated is the average width of all leaves, growing and mature, in a sector of the rosette, measurements being made across the broad distal portion of each leaf with correction for amount of lobing.*

□——□ *number of leaves, 4n;*
○----○ *number of leaves, 2n;*
■——■ *leaf width, 4n;*
●----● *leaf width, 2n.*

leaves increased rapidly to a maximum at 90 to 140 days, declined sharply as senescence overtook new growth and in the diploids increased again in the autumn. The amount of rejuvenescence varied greatly in different individuals, some undergoing little or no revival while others produced more leaves than during the early summer. However, owing to the small size of the autumnal leaves, leaf area generally remained at a low level during rejuvenescence (Fig. 4). On the whole, plants that attained their maximum leaf area earliest in the spring tended to flower first and to have small roots, but many variants occurred. No relationship was detected between the degree of autumnal revival and root size. In some of the large-rooted specimens a marked increase in leaf area ensued during rejuvenescence, while in others there was a steady decline (Figs. 1 and 2). Under some circumstances the decline in leaf area during the summer was more gradual in tetraploids than in diploids. This was true in Series *B*, where the plants remained in the greenhouse during the summer. The tetraploids were less adversely affected by the high temperatures and insect infestations, leaf area diminished less rapidly and the roots were substantially larger than in the diploids.

Leaf form is highly variable in kok-saghyz and attempts have been made to determine the causal factors in this variation and to ascertain whether there is relationship to root weight. That the environment greatly influences leaf shape has been suggested or demonstrated by various authors. For

instance, Goebel (4) has remarked that the leaves of well nourished *Taraxacum* plants are more deeply cut than in depauperate types. In certain of the Russian reports, reviewed by Krotkov (5), the statement is made that favourable conditions cause an increase in lobing in kok-saghyz. Sears (10) has

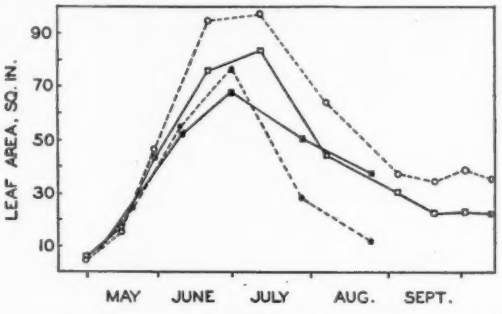

FIG. 4. *Seasonal trends in the average leaf area of all first-year diploids and tetraploids grown from large achenes, Series A (plants moved outside) and Series B (plants kept in greenhouse).*

□———□ *Series A, 4n;*
○---------○ *Series A, 2n;*
■———■ *Series B, 4n;*
●---------● *Series B, 2n.*

described the ontogenetic sequence in leaf shape in *Taraxacum*, pointing out that dissection usually increases with maturation, whereas rejuvenescence restores the juvenile unsegmented type. Most kok-saghyz plants exhibit increased lobing during the rapid expansion of the rosette, but in occasional plants the leaf margins remain entire or become only slightly sinuate. Evidence presented in a previous article (2) indicates that these differences between mature plants are due in part to heredity, the leaves of F_1 plants replicating the parental types. Evidently leaf shape is determined not by any single influence but rather by the interplay of ontogenetical, environmental, and genetical factors.

Some contradictory reports have appeared in the literature (Krotkov (5)) on the relationship between leaf form and root size. Some authors have observed that plants with large roots tended to have deeply cut leaves, and suggested selecting plants with lobed rather than simple leaves. Yet other authors have discounted leaf form as a useful prognostic character for selecting large-rooted plants. An examination of a few hundred F_1 tetraploids grown in pots in 1945 (2) failed to reveal a correlation between leaf shape and root size. However, in the 1946 F_2 plantings from random seed, both diploids and tetraploids exhibited a definite trend (Table V), plants with dissected leaves of Types IV and V (Fig. 5) more often developing large roots than specimens with simple leaves. Further, in the more vigorous Series *A* a slightly larger proportion of the plants had deeply pinnatifid leaves than in the retarded Series *B*. An analysis of the 1945 data also revealed a slightly higher incidence

TABLE V

FRESH ROOT WEIGHT AND LEAF TYPE IN FIRST-YEAR, POTTED PLANTS

Series	Type	No. of plants	Av. root weight in grams of plants with leaf types as indicated				
			I	II	III	IV	V
A (moved outside)	2*n*	55	19.5	25.0	24.9	26.4	30.7
	4*n*	77	15.0	20.3	30.6	35.0	44.7
B (kept in greenhouse)	2*n*	73	—	8.3	8.8	10.7	11.6
	4*n*	89	—	11.8	15.5	18.3	20.5

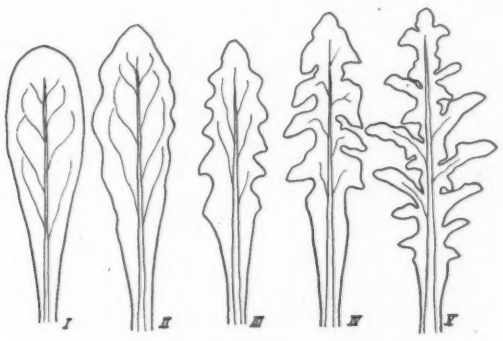

FIG. 5. *Types of leaves in mature tetraploids.*

of deeply lobed leaves among the more vigorous field plants than in potted specimens. These observations, on the whole, give some support to the theory that a favourable environment and luxuriant vegetative growth influence leaf form and increase lobing. It should be emphasized, however, that the average differences in leaf shape between the contrasted groups were often so slight, and individual plants deviated so widely from the general trend that leaf form must be considered of no practical value for detecting large-rooted specimens in a general population.

The relationship between flowering and vegetative characters has also been much studied. Mashtakov *et al.* (6) reported that among crowded first-year diploid kok-saghyz, flowering plants produced larger roots and tops than non-flowering plants. On the other hand, other Russian authors (see Krotkov (5)) believed absence of flowering during the first year to be associated with large root size. Recently, Scarth *et al.* (9) have observed that disbudded 2*n* plants surpassed those that were allowed to produce seed. Roberts and Struckmeyer (8), working with a number of genera, including *Cineraria*, found flowering plants consistently had smaller roots in relation to tops than non-flowering plants. In our 1945 plantings the most floriferous of the tetraploids had roots slightly below average size, but the control diploids

differed, the plants with the most buds being larger than average. However, the number of diploids for which data were available was not great, some of the most prolific of the bud producers were sterile, and there was also considerable disbudding. The 1946 plants were allowed to produce seed and a more positive trend became apparent. In Tables IV and VI it will be noted that flowering declined in the larger plants, and, in the potted tetraploids of

TABLE VI

RELATIONSHIP BETWEEN FRESH ROOT WEIGHT AND FLOWERING IN FIRST-YEAR, POTTED PLANTS

Series	Type	No. of plants	Av. root weight in grams		
			Flowering plants	Non-flowering plants	All plants
A (moved outside)	2*n*	58	25.8	38.4	26.9
	4*n*	79	21.0	35.0	31.2
B (kept in greenhouse)	2*n*	74	9.7	10.8	10.1
	4*n*	89	13.5	16.9	16.4

Series *A* and *B*, none of the plants with roots exceeding 40 gm. flowered. Among the various F_1 families of tetraploids grown in the garden plot from two-year-old seed, 32.5% of plants with roots under 40 gm. flowered and only 13.5% of those with roots exceeding 40 gm. On the whole it would seem that plants that mature late and flower sparsely if at all during the first year tend to have the largest roots. When flowering and seed production do occur they appear to have an adverse effect on root enlargement.

Comparison of Diploids and Tetraploids

A striking feature of tetraploids, as contrasted to diploids, was the more robust nature of their organs. The leaves were usually noticeably wider, the average width in mature rosettes being about 50% greater than in diploids (Fig. 3). This greater width, which was so apparent to the eye, created a false impression as to leaf area. Actually the increase in leaf width was negatived by a decided reduction in leaf number, so that 4*n* leaf area generally fell somewhat below that of contemporaneous diploids (Fig. 4). During the early stages of growth tetraploids sometimes exhibited a minor superiority in leaf area, and occasionally again in late summer because of a prolongation of the period of growth and a less pronounced dormancy, but in none of the parallel series of potted plants where estimates were made did the leaf area of the fully developed rosette in tetraploids exceed that in diploids. In this connection it might be noted that the estimates of leaf area were calculated from the number, average length, and width of the leaves with correction for shape and degree of lobing.

In both diploids and tetraploids the number of leaves increased from the first to the second year, and was greater in field than in potted plants. The largest of the second-year field tetraploids had up to 200 leaves, rosettes to 22 in. in diameter, and produced as many as 150 inflorescences in the spring period of blossoming. In all parallel series, however, the diploids had many more leaves than tetraploids. To accommodate the profusion of leaves the diploids more often possessed multiple crowns than the tetraploids.

As in the case of the leaves the tetraploid capitula were generally larger than the diploid, but productivity was drastically reduced. In the various parallel series of first-year diploids and tetraploids grown under similar conditions from year-old untreated seed, 4*n* head production was only 1/10 to $\frac{1}{4}$ that of diploids. This difference was narrowed in the second year, when some of the tetraploids flowered profusely. As shown by comparison of the 1945 and 1946 plantings of Crosses 86 × 71 and 71 × 86 (Table II) ageing of the seed for another year caused a marked diminution in flowering. This was noted in both diploids and tetraploids.

The root systems of diploids and tetraploids exhibited the same fundamental differences in organization as the aerial parts. The tetraploids tended to have thicker less divided roots, though individuals were highly variable as illustrated in Fig. 6. Both unbranched tap roots and finely divided fibrous systems with many prominent secondaries occurred in tetraploids and diploids, but stout tap roots were more common among the tetraploids and diffuse fibrous systems more prevalent among the diploids. The bearing of these

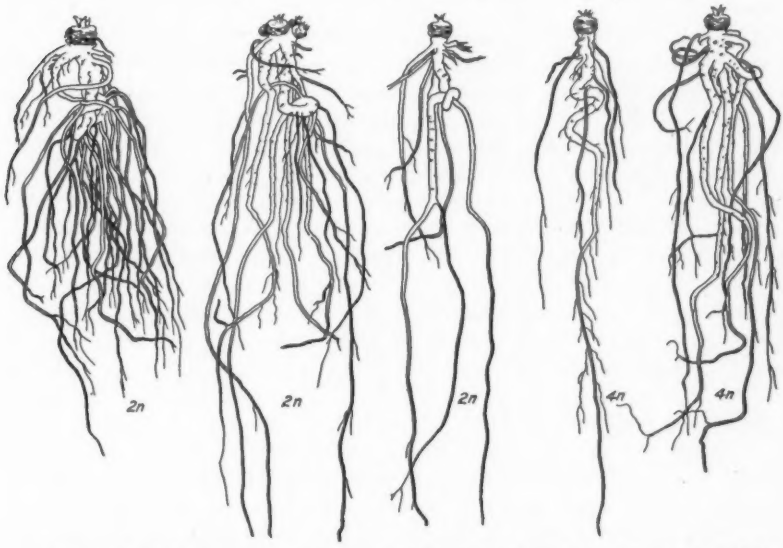

FIG. 6. *Types of root systems in first-year diploids and tetraploids. From left to right weights were 38, 48, 33, 23, and 45 gm. Mag. × 1/6.*

basic differences in root habit on such problems as removal of roots from the soil and extraction of rubber should be recognized when contrasting diploids and tetraploids.

Although the tetraploid roots were inclined to be more robust than the diploid, the increase in thickness was counteracted by reduction in number of divisions so that little difference in total weight was observed between comparable plants. For instance, in the first-year plants of Series *A* (Table VI) it will be noted that the average root weight of flowering diploids and tetraploids corresponded, being 25.8 and 21.0 gm., respectively. Similarly in the non-flowering plants of the same series the $2n$ and $4n$ roots were much alike though substantially heavier at 38.4 and 35.0 gm. When floriferous first-year diploids were disbudded to make them comparable with sparsely flowering tetraploids, their root weight approximated that of the latter. On the other hand, when second-year diploids were disbudded and the more profusely flowering second-year tetraploids allowed to set seed the latter plants developed definitely inferior roots. It would appear from these data that flower and seed production have an inhibiting effect on root formation. Cognizance must be taken of this relationship when contrasting diploids and tetraploids. Since the production of $4n$ heads during the first year is much lower and the proportion of non-flowering plants higher than in diploids, the average root weight of the tetraploids tends to surpass that of the diploids, unless the latter are disbudded. From the standpoint of root production tetraploids may prove economically superior to diploids because of their sparse first-year flowering.

It should perhaps be emphasized that the seed used in our experiments was stored at room temperature, and was not chilled prior to germination. Certain Russian investigators (Krotkov (5)) found that exposure of diploid seeds to temperatures of 0° to 2° C. before germination hastened flowering. Borthwick *et al.* (3) also reported that plants that received low temperatures during their early development flowered more abundantly than untreated plants. If, as appears to be indicated by the data accumulating from various sources, flower and seed production hinder root formation, it would seem advisable to avoid pregermination chilling or other practices that stimulate flowering.

Ageing of the seed for another year still further reduced the flowering of first-year plants. This was most clearly demonstrated by the 1946 and 1945 plantings in pots of the F_1 progenies of 71 × 86 and 86 × 71 (Table II). Flowering was virtually eliminated in the 1946 plants derived from the same seed lots as used in 1945. Tetraploids set out in the garden plot were more floriferous but here again blooming was much reduced as compared with plants of the previous year. Likewise among a small lot of 31 random potted diploids grown from two-year-old seed only three plants flowered. Effect of age of the seed on vegetative growth was not accurately determinable because of the lack of control series. Growth of the tetraploids did not seem impaired, but there were some indications of a slight relative reduction in vigour among the diploids.

Discussion

When large or small tetraploid kok-saghyz plants were crossed among themselves they did not bear achenes reflecting the difference in stature of the parents, nor did achene size appear to be an important factor in determining ultimate size of derivative plants when these were grown separately. However, since the early growth of seedlings derived from large achenes sometimes exceeded that of seedlings grown from small achenes, especially in the case of the diploids, achene size may be an important factor when competition exists in close planting.

Mature tetraploids differed from diploids in possessing larger but fewer divisions of the plant body, increase in size being counteracted by reduction in number. For instance, leaf width was approximately 50% greater in tetraploids than in diploids, but owing to the greatly curtailed rate of leaf production the leaf area of tetraploids failed to exceed that of diploids in any of the parallel series where estimates were made. The general statement of Navashin *et al.* (7) that tetraploid kok-saghyz was distinguished from the diploid by an increase of all the cells, organs, and the plant as a whole was not confirmed in so far as it relates to the plant as a whole. Whether the differing conclusions are to be ascribed to the fact that Navashin's observations were based on field plants and the present author's largely on potted plants is not clear. The 1945 plantings gave some indication that favourable field conditions might be more conducive to the development of a superiority among the tetraploids than growth in pots, but the number of control, potted plants was too small for adequate comparison.

During the early stages $4n$ seedlings were more robust than $2n$ seedlings and leaf area was slightly greater. After the first month, however, the leaf area of tetraploids tended to fall slightly behind that of diploids. As a rule the tetraploids matured shortly after the diploids, the attainment of maximum size of the rosette and the inception of flowering occurring a few days later. Without providing statistics, Navashin *et al.* (7) reported no difference in the proportion of $4n$ and $2n$ plants blooming in the first year. This was definitely not the case in the Toronto plantings. The tetraploids were notably less floriferous than diploids, both in the proportion of flowering plants and head productivity per plant. Again the differing observations may be partially explicable by dissimilar seed treatments and conditions of growth. The seed used locally was not given pregermination chilling since such treatment was not considered generally beneficial.

On the whole, plants that possessed broad leafy rosettes, matured late, and flowered sparsely if at all during the first year tended to have the largest roots, though some individuals deviated from the general trend. When flowering and seed production occurred they appeared to have a retarding influence on root enlargement. Since the tetraploids were less floriferous than diploids they were correspondingly freed from the inhibiting effects of flower and seed development, and in that respect had an advantage over diploids. Thus

under certain combinations of internal and environmental conditions tetraploids would be expected to produce larger roots than diploids. That the degree of such superiority fluctuates with the various factors affecting growth is attested by the differing observations of Navashin *et al.* (7), Warmke (11), and Bannan (2).

Acknowledgments

This paper is the third report on a project assisted financially by the National Research Council of Canada and the University of Toronto. Facilities were made available by Prof. H. S. Jackson, Head of the Department of Botany, University of Toronto. To Prof. G. H. Duff I am indebted for his constant interest. For technical assistance thanks are due Miss M. B. Brown and Miss B. E. Whalley.

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ERYSIPHE GRAMINIS IN CANADA[1]

By Margaret Newton[2] and W. J. Cherewick[3]

Abstract

A study has been made of powdery mildew (*Erysiphe graminis* DC.) in Canada, including its distribution, the physiologic specialization of its two varieties, *Hordei* and *Tritici*, and the reactions of barley and wheat hosts to the prevalent races of the two varieties of mildew. The fungus occurs throughout Canada but it is most prevalent in British Columbia, Ontario, and Quebec. Nine races of *E. graminis Hordei* and three of *E. graminis Tritici* have been identified. Races 3, 6, 8, and 9 of the former, and races 4 and 5 of the latter are the most common in Canada. At a higher temperature (25° C.) practically all the races of mildew developed a more resistant type of infection than at a lower temperature (15° C.). The only exception was race 6 of *E. graminis Hordei*, which thrived fairly well at the higher temperature.

The reactions of 246 varieties and strains of barley to nine races of barley mildew and the reactions of 124 wheat varieties and strains to two races of wheat mildew indicate that there are varieties of both cereals that are resistant to powdery mildew.

Powdery mildew, *Erysiphe graminis* DC., is present on wheat, oats, barley, rye, and many grasses in Canada. How far back in the history of Canadian agriculture mildew became established on cereals is not known. The first collections of mildew in Canada were apparently those of Dearness,* in 1891, on a grass at London, Ont. and, in 1898, on fall wheat at Granton, Ont. Salmon (15), in 1900, reported the presence of powdery mildew in Ontario, and Fraser (5), in 1909, stated that, in Nova Scotia, *E. graminis* "occasionally causes serious damage to grain crops". In 1910, Dimitriou (4, pp. 16-19) reported mildew as abundant and destructive on certain varieties of wheat, barley, and rye in Quebec. It was not until 1921, when the plant disease survey was started in Canada, that systematic records of mildew were made in all parts of Canada. From 1921 to 1945, these records show that powdery mildew was present in Canada every year during that 25-year period, with the possible exception of 1924 when no survey was carried out. It has occurred in every province of Canada, as well as in the North West Territories (11), where, in 1940, the senior author found it on wild grasses along the Mackenzie River as far north as Arctic Red River, approximately 65 miles north of the Arctic Circle.

Powdery mildew constitutes a definite hazard in cereal production in certain parts of Canada (2; 3; 4, pp. 16-19). No specific experiments have been carried out to appraise the actual yearly damage from powdery mildew on

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* *Dates of collections were kindly supplied by Dr. John Dearness. The collection made in 1891 was reported, in 1893, by Ellis and Everhart (N. Am. Fungi 2813 on leaves of grass at London, Ont. J. Dearness).*

cereals but reports have shown that definite losses have occurred. In British Columbia, in 1936, Foster* estimated the damage from powdery mildew on the wheat variety Little Club to be 87% and on the oat variety, Bond, 20%. Reports from Ontario and Quebec refer to barley mildew as the most destructive disease of barley, and wheat mildew as causing considerable damage on winter varieties. A report from Quebec (2**) states, "Winter wheat was severely infected by powdery mildew—80% of the plants were infected, and, at maturity, the heads of these were only half-filled". In the Prairie Provinces, oat mildew has not been reported. Wheat and barley mildew are less prevalent there than in the other provinces and frequently develop too late to bring about material losses. In certain years in the Prairie Provinces (3), however, mildew has been destructive both on barley and on wheat, particularly in localized areas.

Because of the prevalence of wheat and barley mildew in certain parts of Canada, considerable attention has been given to the problem of controlling this disease by the development of resistant varieties. Before breeding programs could be effectively carried out, information was necessary on the occurrence and geographical distribution of physiologic races of wheat and of barley mildew, the environmental conditions governing the spread of these races, and the relative resistance of varieties to them. It was with a view to securing this information for the plant breeders that the present investigation was undertaken in 1934.

Specialization of *Erysiphe graminis*

That powdery mildew of cereals and grasses is specialized into varieties, "Formes specialisées", was first demonstrated by Marchal (10) in 1902. He distinguished seven physiologic varieties of mildew: *Tritici* on species of *Triticum; Hordei* on species of *Hordeum; Secalis* on species of *Secale; Avenae* on species of *Avena; Poae* on species of *Poa; Agropyri* on species of *Agropyron;* and *Bromi* on species of *Bromus.* Homma (6), 27 years later, reported an additional variety of mildew: *Elymi* on *Elymus mollis.*

The significance of Marchal's discovery of specialization stimulated further research, and Salmon (16) in Europe and Reed (12) in the United States made extensive tests with mildew on grasses and cereals. They confirmed much of Marchal's work and, in addition, found that the varieties described by him were not necessarily the ultimate units of specialization. Salmon found evidence that the mildew on *Bromus* spp. could be subdivided into four or possibly five physiologic races—"biologic forms"—and Reed showed that the mildew on *Poa* spp. consisted of "more than one at least partially differentiated physiologic form".

It remained for Mains and his co-workers to prove that specialization also existed in *E. graminis* attacking cereals. In 1930, Mains and Dietz (9)

* *Unpublished data by W. R. Foster, Provincial Department of Agriculture, Victoria, B.C.*
***Twelfth Annual Report of the Canadian Plant Disease Survey, p. 7. 1932.*

described five physiologic races of *E. graminis Hordei* Marchal in the United States and, in 1937, Tidd (18) reported two additional races in that country. In Germany, in 1934, Honecker (7) identified nine physiologic races of mildew but, owing to the fact that he used but one of the differential hosts used by Mains and Dietz and other North American workers, his races cannot be compared with those isolated in America. In Canada, four races of barley mildew were reported in 1935 (2*) and three in 1944 (3). Since 1944, two additional races have been isolated, making a total of nine physiologic races isolated in Canada.

Specialization within the variety *E. graminis Tritici* Marchal was first established by Mains (8). From 1923 to 1933, he tested the reactions of a large number of wheat varieties to mildew, and by the reactions of the varieties Axminster and Norka established two pathogenically distinct races. In Germany, Rosenstiel (14), in 1938, found evidence of specialization in this organism, and Schlichtling (17), in 1939, isolated six distinct races that, apparently, were all different from the two recognized by Mains. In the same year, Waterhouse (20) reported three races in Australia, and Vallega (19), in 1941, three in South America. In Canada, the present authors isolated three physiologic races of *E. graminis Tritici*. As the investigators outside North America worked independently of each other, their respective physiologic races were identified by means of different groups of differential hosts with the result that the races of *E. graminis Tritici* in different countries are not necessarily comparable.

Identification of Physiologic Races of *Erysiphe graminis*

The Differential Varieties

The differential varieties of barley used in Canada in the identification of physiologic races of barley mildew were the same as those used by Mains and his co-workers (9, 18), with the addition of Chevron C.I. 1111 (3). The wheat varieties, used in the identification of wheat mildew, were the same as those suggested by Mains (8). Owing to the fact that different selections of the same agronomic variety of a cereal may react quite differently to certain races of mildew (8, 9), the seed of most of the differential hosts was originally obtained from Mains and subsequently attempts were made to keep it as pure as possible.

Source of Cultures

Cultures were established from both conidia and perithecia. Because of the fact that, at temperatures above freezing, conidia of *E. graminis* germinate within 24 hr. (3) very few cultures were established from conidia taken from specimens sent through the mail. Cultures were secured quite often, however, from specimens that had been four to five days in transit when the infected plants were packed loosely in a cardboard box or cylinder with the roots or cut ends wrapped in moist material so as to maintain the specimens in a living

* *Fifteenth Annual Report of the Canadian Plant Disease Survey, p. 13. 1935.*

condition. Such specimens, when received, were usually devoid of viable conidia, but fresh conidia developed within 24 hr. upon floating the infected leaves on a 10% sucrose solution.

A number of cultures were established from perithecial material sent through the mail in ordinary paper envelopes. Such material has been kept by the writers for three years in a refrigerator at approximately 3° C., with no appreciable loss of viability. After it was shown (3) that alternating temperatures induce perithecial development, and that perithecia alternately wetted and dried develop ascospores, the pure cultures of physiologic races were frequently stored from season to season in the perithecial stage.

Inoculation Methods

Host seedlings were grown in 4-in. pots with from 20 to 30 seedlings per pot. The seedlings in the pots were protected from stray mildew spores by glass chimneys with inverted Petri dishes placed on top of them or by being kept in special isolation booths with glass on three sides, glass or cellophane on top, and cotton curtains in front.

The seedlings were inoculated when the first leaf was about 4 in. long. When conidia were used as inoculum to establish a culture, they were applied to the surface of a leaf by means of an inoculating needle with a spatulate metal tip, or by drawing a conidium-bearing specimen over the leaf to be inoculated. Since conidia germinate at a relatively low humidity (1, 3, 21), the inoculated plants were left in the isolation booths without incubation in moist chambers. When perithecia were used to start a culture, the specimen was first soaked in water until ascospores began to form. It was then fixed on a moist filter paper in a Petri dish and this was placed on top of a glass chimney over the seedlings for 24 to 48 hr. Transpiration by the seedlings was usually sufficient to keep the filter paper damp.

When a culture had been established seedlings of the differential hosts were inoculated with it by shaking over them, within the isolation booth, a pot of heavily infected seedlings bearing an abundance of viable conidia.

The Isolation of Pure Races from Mixed Cultures

It was a common experience when field cultures of either conidial or perithecial origin were studied to find that two or more physiologic races were present in the same culture. A number of these races could be detected by a casual inspection of the reactions of the differential hosts. For example, a mixture of races 1 and 3 of *E. graminis Hordei* would result in two types of infection, "1" and "4", on Black Hull-less, Nepal, and Peruvian barley seedlings (see Table II). In such instances a separation of races was effected by making single-pustule isolations from both types of infection and then transferring the conidia to susceptible hosts in separate isolation booths. Other races, such as 10 and 3, when mixed were more difficult to separate and, therefore, single-pustule isolations through several generations of the organism were often necessary. In certain cases, however, single-spore isolations were

made before the identity of the race was definitely established. The identity of a new race was never finally established until several single-spore isolations had been made and their infection types on the differential hosts had been compared with those of the known races.

The Effect of Temperature on the Determination of Physiologic Races of *Erysiphe graminis*

Difficulties have been experienced by the writers, as well as by other investigators (3, 13), in maintaining cultures of powdery mildew in the greenhouse during the summer months. Still greater difficulties were encountered in the determination of physiologic races during such periods. Races identified in the spring, when again tested during the summer months, usually produced considerably weaker infections. Temperature appeared to be the main limiting factor and, therefore, a number of tests were made to determine the effect of temperature on the development of powdery mildew.

Duplicate sets of seedlings of the differential hosts of wheat and barley were inoculated separately with each of six races of *E. graminis Hordei* and one race of *E. graminis Tritici* and were placed in two adjacent compartments of a temperature-controlled greenhouse. In one compartment the mean temperature was held at approximately 25° C., and in the other at approximately 15° C. These temperatures were chosen after it was found by preliminary tests that the development of mildew was completely arrested when the host plant was kept continuously at a temperature above 25° C. On the other hand, development was very slow when the host plant was kept continuously below 15° C. The tests were repeated three times.

The average infection types produced by six physiologic races of *E. graminis Hordei* on six differential hosts are summarized in Table I. The infection types of the one race of *E. graminis Tritici*, that was included in the test, were affected by the two different temperatures in the same way as those of *E. graminis Hordei*.

Although the effect of temperature varied slightly with different races on different hosts (Table I), the development of mildew in general was appreciably less at the higher temperature. The infection types shown in Table I were recorded at the time of maximum development of the disease; that is, six to eight days after inoculation in the hot house (25° C.) and 11 to 14 days after inoculation in the cold house (15° C.). Two to three days after the maximum development had been reached at the higher temperature, mildew pustules ceased to produce conidia and turned into a resistant type of infection with thin mycelial mats. There was little, if any, secondary infection. The only exception was in the case of race 6 of *E. graminis Hordei*, which thrived fairly well at the mean temperature of 25° C., a fact indicating that not all the races of mildew are equally responsive to temperature changes. At the lower temperature both wheat and barley mildew pustules continued to sporulate, with an abundant development of secondary infections, until the host seedlings were killed.

TABLE I

MEAN INFECTION TYPES[1] PRODUCED BY SIX PHYSIOLOGIC RACES OF *Erysiphe graminis Hordei* ON SEEDLING LEAVES OF SIX BARLEY VARIETIES AT TWO DIFFERENT TEMPERATURES

Host	Physiologic races											
	3		4		6		8		9		10	
	Temperature, ° C.											
	25°	15°	25°	15°	25°	15°	25°	15°	25°	15°	25°	15°
Black Hull-less	3−	3+	3	4	1	1+	3	4−	2−	1	3−	2
Chevron	;	1−	0	0	1−	1−	3−	4	3−	4−	1	1−
Goldfoil	0	0	;	1−	0	0	0	0	0	0	0	0
Heil's Hanna	3+	4	4−	4+	4	4−	4−	4+	3+	4	4−	4+
Nepal	3	4	3+	4	2−	1+	3−	4−	2+	2−	3	2−
Peruvian	2	3+	1−	1+	1−	1	1	1	1+	1	3−	3

[1]*Explanation of symbols*

0—*immune—no visible signs of infection.*

;—*highly resistant—chlorotic or necrotic flecks present with no visible development of mycelium.*

1—*highly resistant—with a slight development of mycelium.*

2—*moderately resistant—moderate development of mycelium with a slight production of conidia. Chlorotic or necrotic spots present.*

3—*moderately susceptible—moderate to abundant development of mycelium accompanied by moderate sporulation. Chlorotic or necrotic spots may be present.*

4—*very susceptible—large pustules abundantly sporulating. No necrotic spots.*

(+) and (−) signs indicate quantitative increase or decrease in the infection type.

The responsiveness of mildew infections to temperature changes emphasizes the importance of identifying physiologic races, as far as possible, under conditions of constant temperature. Owing to the fact that identification work has to be done in greenhouses where temperatures may run above 25° C., particularly during late spring and summer months, a knowledge of the way in which temperature influences mildew reactions is important, and makes it possible to gauge to some extent the modifications brought about by variations in temperature.

Studies reported in this paper, on both physiologic specialization and the reactions of varieties and strains of barley and wheat to powdery mildew, were made in a greenhouse maintained at a mean temperature of approximately 20° C.

Physiologic Races of *Erysiphe graminis Hordei*

During the first five years of the survey (1934 to 1939) races 1, 3, 4, and 6 were isolated (Table II). These four races resemble one another in their inability to infect Chevron (C.I. 1111), a barley that in Canada, prior to 1940, proved to be highly resistant to both mildew and stem rust and was used

Analytical key for the identification of physiologic races of *Erysiphe graminis Hordei* on the basis of their pathogenicity on six selected differential varieties of barley.

Goldfoil susceptible
- Black Hull-less susceptible — 5
- Black Hull-less resistant
  - Chevron susceptible — 12
  - Chevron resistant — 7

Goldfoil resistant
- Chevron susceptible
  - Nepal susceptible
    - Peruvian susceptible — 11
    - Peruvian resistant — 8
  - Nepal resistant — 9
- Chevron resistant
  - Peruvian susceptible
    - Nepal susceptible — 3
    - Nepal resistant — 10
- Peruvian resistant
  - Black Hull-less susceptible — 4
  - Black Hull-less resistant
    - Nepal susceptible — 2
    - Nepal resistant
      - Heil's Hanna susceptible — 6
      - Heil's Hanna resistant — 1

TABLE II

MEAN INFECTION TYPES PRODUCED ON SEEDLING LEAVES OF SIX VARIETIES OF BARLEY BY 12 PHYSIOLOGIC RACES OF *Erysiphe graminis Hordei*

Physiologic race	Black Hull-less C.I. 666	Chevron C.I. 1111	Goldfoil C.I. 928	Heil's Hanna 3 C.I. 682	Nepal C.I. 595	Peruvian C.I. 935
1	0–2	0–;	0	1–2	1–2	0–1
2*	1–2	0–1	0	4	4	1
3	3	0–1	0	4	4	3–4
4	4	0–;	0–;	3–4	4	1
5*	3	–	4	4	4	4
6	0–2	0–1	0	3–4	0–1	0–1
7*	0–1	0–;	3–4	3–4	0–1	0–1
8	3	3–4	0	3–4	3–4	0–1
9	1–2	4	0	4	1–2	0–1
10	1–2	0–1	0	4	1–2	3
11	4	4	0	4	4	4
12	1	3	4	4	1–2	1

* *Races not isolated by writers.*

quite extensively in breeding work. In that year, P. R. Cowan, Cerealist, Central Experimental Farm, Ottawa, reported that, in his plots, Chevron barley was heavily infected by mildew. Subsequent studies showed that the mildew collected by him on Chevron barley could not be distinguished from race 4 except by the reaction of Chevron; and this made it advisable to add Chevron to the list of five differentials selected by Mains and his colleagues (9, 18) for the identification of physiologic races of barley mildew.

TABLE III

DISTRIBUTION BY GEOGRAPHICAL AREAS OF PHYSIOLOGIC RACES OF *Erysiphe graminis Hordei* FROM 1934 TO 1945. (FIGURES REPRESENT THE NUMBER OF TIMES EACH RACE WAS COLLECTED IN EACH GEOGRAPHICAL AREA)

Physiologic race	Quebec and Ontario												Prairie Provinces												British Columbia												Total
	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	
1	1													1																							2
3														1							3	1			1						2	2		1	1	2	14
4			1											1		1				2	1												1				7
6			1					1								1	1		3	2	3	1	1														14
8							1	2	1	2	2	2								1	1														1		13
9									1	2	3	2								3	1														1		13
10																				1	2		1														4
11											1																								1		2
12												2																									2
Total	1		2				1	3	2	4	6	6		3		2	1		3	9	11	2	2		1						2	2	1	1	4	2	71

Between 1940 and 1945, notable changes took place in the common races (Table III). Five new races were identified, of which four attacked Chevron, namely, races 8, 9, 11, and 12. These four races comprised 50% of the isolates during that period, and they already form a potential threat to newly developed barley varieties with the Chevron type of resistance.

Two of the races that attack Chevron, races 8 and 9, together with races 3 and 6, constitute the prevalent races in Canada.

Races 10 and 11 were isolated only from perithecial cultures. The former was isolated four times from perithecia collected in Manitoba, and the latter from perithecia sent from Ontario and British Columbia.

Races 2, 5, and 7 identified in the United States (9, 18), have not been found in Canada.

The annual distribution of the nine physiologic races of *E. graminis Hordei* isolated in Canada from 1934 to 1945, races 1, 3, 4, 6, 8, 9, 10, 11, and 12, is shown in Table III.

Physiologic Races of *Erysiphe graminis Tritici*

Annual surveys of the prevalence of physiologic races of wheat mildew, *E. graminis Tritici*, have not been conducted in Canada but, from 1933 to 1944, a total of 27 cultures from British Columbia, Alberta, Manitoba, Ontario, and Quebec were studied.

Until 1943, only one physiologic race was identified. This race, isolated in Manitoba, attacked the wheat varieties Huron and Chul, but not Norka and

TABLE IV

MEAN INFECTION TYPES PRODUCED ON SEEDLING LEAVES OF FOUR VARIETIES OF WHEAT BY FIVE PHYSIOLOGIC RACES OF *Erysiphe graminis Tritici*

Races 1 and 2 were isolated in the United States by Dr. E. B. Mains.
Races 3, 4, and 5 were isolated in Canada by the present authors.

Race	Axminster R.L. 75	Chul R.L. 543	Huron R.L. 20	Norka R.L. 1888
1 (United States)	0	0	0–1	0
2 (United States)	0	0	0	4
3 (Canada)	0	4	4	0
4 (Canada)	0	0	4	0
5 (Canada)	4	0	4	4

Analytical key for the identification of physiologic races of *Erysiphe graminis Tritici* on the basis of their pathogenicity on four selected differential varieties of wheat.

Axminster susceptible	5
Axminster resistant	
Chul susceptible	3
Chul resistant	
Norka susceptible	
Huron susceptible	4
Huron resistant	2
Norka resistant	1

Axminster (Table IV). In 1943 seven cultures from Manitoba were studied. They attacked the variety Huron but not Chul, Norka, and Axminster. In 1944, a culture that attacked Huron, Norka, and Axminster but not Chul (Table IV) was obtained from an Ontario specimen. The infection types of the three Canadian races, as well as those of races 1 and 2, the first to be isolated in America (8) are included in Table IV. A study of these infection types makes it clear that the three races identified in Canada are all different from the two described by Mains, and that they should be designated as new races. They are tentatively numbered races 3, 4, and 5 (Canada). A key for the identification of the five races found in North America is included with Table IV.

Relative Resistance of Barley and Wheat Varieties to Powdery Mildew

A study of the relative resistance of varieties and strains of barley and wheat to physiologic races of powdery mildew was undertaken chiefly to assist plant breeders in Canada in choosing suitable breeding material and in developing resistant varieties.

These tests were made in the greenhouse where each variety could be studied for its reaction to individual races of mildew. Such tests are considered to be more reliable than field tests because powdery mildew does not develop to the same extent year after year in any one district, nor do all races occur in a district at the same time. In the greenhouse also, the reactions of varieties in the seedling stage may be determined quickly and accurately. Since all the varieties tested by the authors and found to be resistant to mildew in the seedling stage have also proved to be resistant in the adult stage, it should be possible to select resistant varieties on the basis of seedling tests. There are some varieties, however, in which the seedlings and adult plants do not react identically to powdery mildew. Some variation in varietal reaction to powdery mildew has been shown by the writers to be due to environmental conditions, particularly temperature, but even under similar conditions, some varieties are more resistant in the adult than in the seedling stage. Such varieties possess so-called adult plant resistance.

Tidd (18), in his study of races 6 and 7 of *E. graminis Hordei*, obtained a greater degree of adult plant resistance in the spring than during the winter. He mentions, however, that the temperature in the spring went up to 32.2° C. while in the winter it ranged between 12.7° and 24° C. In the tests made by the authors it was found that no host that was completely susceptible in the seedling stage showed complete resistance in the adult stage. Nevertheless, a number of varieties, particularly of durum wheat, possess a high degree of adult plant resistance (Table V).

Varieties of cereals possessing the adult plant type of resistance (Table V) might be expected to have considerable value as breeding material, but a still better starting point for a breeding programme, having as its object the development of mildew resistant varieties, would be to choose as parental

TABLE V

A COMPARISON OF THE INFECTION TYPES ON SEEDLING AND ADULT PLANTS OF FIVE VARIETIES EACH OF WHEAT AND BARLEY INOCULATED WITH *Erysiphe graminis Tritici* RACE 4 AND *E. graminis Hordei* RACE 3

Variety	Accession No.	Infection types	
		Seedlings	Adult plants
Wheat			
Gaza	R.L. 1664	4	1+
Kanred	" 1443	4−	2+
Mindum	" 568	4	1+
Pentad	" 203	4	1+
Thatcher	" 1945	4	4
Barley			
Blackhull	C.I. 878	4	2
Black Hull-less	" 666	4	2+
Bolivia	" 1257	2	0
Flynn	" 1311	3	2
Heil's Hanna	" 682	4	4

material suitable varieties known to be immune or highly resistant in the seedling stage.

Many of the varieties tested in the present investigation have been developed recently, but for purposes of comparison some of the older standard varieties have been included as well. All the varieties of barley tested are listed in Table VI. Those having Canadian accession numbers are placed first; those with United States cereal introduction numbers last.

As pointed out elsewhere in this paper, in most cases varieties develop increased resistance to mildew at higher temperatures. In the present greenhouse tests, special precautions were taken to prevent the temperatures from becoming excessively high at any time.

TABLE VI

INFECTION TYPES ON 246 BARLEY VARIETIES AND STRAINS INOCULATED IN THE SEEDLING STAGE WITH NINE PHYSIOLOGIC RACES OF *Erysiphe graminis Hordei*

Variety or strain	C.A. No.	Infection types with physiologic races								
		1	3	4	6	8	9	10	11	12
Hordeum vulgare										
Aethiops	892	1	2+	2	1	2−	2	2+	1	1
Algerian	10	−	0	;	;	0	;	0	1=	;
Arlington Awnless	882	−	−	;	;	−	1−	;	−	1−
Atlas	702	2	4	1−	2	1	1	4	3−	1
Atrum	888	1	2−	2	2−	2+	1+	2	1−	2−
Baker	87	−	−	4	3	−	4	4	4	4
Bark	703	4−	4	4	4	4	4	4	4	4
Bay Brewing	707	4	4	4	4	4	3	4	−	1
Beecher	1153	−	3+	4−	4	4	4−	4	3	1

TABLE VI—*Continued*

INFECTION TYPES ON 246 BARLEY VARIETIES AND STRAINS INOCULATED IN THE SEEDLING STAGE WITH NINE PHYSIOLOGIC RACES OF *Erysiphe graminis Hordei*—*Continued*

Variety or strain	C.A. No.	Infection types with physiologic races								
		1	3	4	6	8	9	10	11	12
Hordeum vulgare—Continued										
Beldi Giant	1024	2+	3+	2+	3+	4	2+	3	4	2
Black Barbless	11	3	4	3	4	4	4	2+	2+	4
Black Hull-less	761	2+	4	4	1+	4	1	1+	4	2
Blue Hull-less	760	3	4	4	2+	4	1+	1	4−	1
Bolivia	12	−	1+	1+	3+	1	1+	2+	1+	1−
Byng	1096	−	4	4	4	4	4	4	4	4
California Brewing	706	−	4	4	4	4	4	4	4	4
California Feed	26	−	3	4−	4	4	3+	4	4	4
California Mariout	1083	4−	4	4	4	4	4	4	4	4
Cape	708	−	4	4	4	3+	3+	4	4	3
Chevron	1121	−	1−	;	1	3+	4−	1−	3	4
Chillian Brewing	709	−	2+	3	3+	1	2+	4	1	3−
Club Mariout	729	3−	4	4	4	4	4	4	3+	3−
Coast	13	4	4	4	4	4	4	4	4	4
Coast	711	−	3	4	3−	4	4	−	−	−
Coerulescens	17	−	2	1+	2+	2+	1+	4	1	1=
Colsess	772	2	3	1	1+	2	1	4	2+	1
Danubian	1020	4	4	4	4	4	4	4	4	4
Duplex	1129	−	0	1−	0	;	1+	;	1+	2
Eurylepsis	15	−	4	4	4	4	4	4	4−	4
Featherston	715	4	4	4	4	4	4	4	4	4
Flynn	1032	3	3	1−	1+	1	1−	4	1−	1−
Galore	1126	−	4	4	4	4	4	4	−	4
Galore × Duplex	(Guelph)	−	;	;	;	;	1−	;	;	1−
Garton	1134	4	4	4	4	4	4	4	4	4
Gatami	717	2+	2	2	2−	1+	2+	2−	4	1
Glabron	718	4	4	4	4	4	4	4	4	4
Hero	719	3	4	4	4	4	4	4	4	4−
Horsford	777	4	4	4	4	4	4	4	4	4
Horsford	84	−	3	4	3	3+	3−	4	4	3−
Horsfordianum	887	4	4	4	4	4	4	4	4	4
Icelandic	90	−	4	4	4	4	4	4	4	4
Juliaca	43	−	3	4	4	4−	4	4−	2	4
Kindred	1155	−	4	4	3	4	4	3+	4	4
Lico	1152	−	4	3	3	2+	4	4	2	1
Lion	86	4	4	4	3+	4	4	4	4	4
Malting	92	−	4	3+	4	4	4	4	4	4
Manchuria	724	4	4	4	4	4	4	4	4	4
Manchurian	726	4	4	4	4	4	4	4	3	4
Mansfield	1056	4	4	4	3	4	4	4	4	4
Mariout B113	91	−	2+	4	4−	3	4	3	4	2−
Mariout B	1130	−	2+	2+	3+	2+	2+	−	−	−
Mensury	730	−	4	4	4	4	4	4	3+	4
Mensury Ott. 60 × Duplex	79	−	1+	1+	1−	0	1	1−	1−	1
Mensury Ott. 60 × Duplex	80	−	0	0	0	;	1	0	;	1
Mensury Ott. 60 × Duplex	81	−	0	;	0	1−	1−	0	1−	1=
Michigan Black	28	4	4	4	4	4	4	4	3	4
Minsturdy	732	1=	2+	1	1+	1−	1	1	1+	1+
Montcalm	1135	−	4	4	4	4	4	4	4	4
Morocco	1131	−	4	1	1+	1	1−	4	2+	1−
Nepal	779	2+	4	4	1	4	2+	1	4	1
Newal	1089	−	4	4	4	4	4	4	4	4

TABLE VI—*Continued*

INFECTION TYPES ON 246 BARLEY VARIETIES AND STRAINS INOCULATED IN THE SEEDLING STAGE WITH NINE PHYSIOLOGIC RACES OF *Erysiphe graminis Hordei*—*Continued*

Variety or strain	C.A. No.	Infection types with physiologic races								
		1	3	4	6	8	9	10	11	12
Hordeum vulgare —Continued										
Nobarb	1143	4–	4	4	4	4	4	4	4	4
Nobarb × Duplex	(Guelph)	–	;	;	0	1–	;	;	;	;
O.A.C. 21	1086	4	4	4	4	4	4	4	4	4
O.A.C. × Peatland	35	–	4	4	4	4	4	4	4	4
O.A.C. × Peatland	38	–	4	4	4	4	4	4	4	4
Oderbrucker	29	4	4	4	4	4	4	4	3+	4
Oderbrucker	89	–	4	4	4	4	4	4	4	4
Odessa	738	3+	3	4	4	4	4	4	4	4
Olli	739	–	2	4	4	4	4	4	3	4
Oregon	1061	–	1+	2+	1+	3+	2+	2	2+	2–
Orge B100	30	–	4	4	4	4	4	4	4	4
Orge 14 B101	31	–	3+	4	4	4	4	4	3+	4
Ottawa 1557A	1137	–	4	4	4	2+	4	4	–	–
Ottawa 1559A	1138	–	4	4	4	3+	4	4	–	–
Ottawa 1559B	1127	–	2+	4	4	3+	4	4	–	–
Ottawa 1947E	45	–	2+	4	4	2+	4	4	–	–
Pallidum	18	4	3+	4	4	4	4	4	4	4
Pallidum	19	–	4	4	4	4	4	4	4	4
Pallidum	20	–	3+	4	4	4	4	4	4	4
Pannier	1042	–	4	4	3+	4	4	4	4	4
Pearl	780	2	3	4–	1+	3+	2	1+	3	1=
Peatland	722	4	4	4	4	4	4	4	4	4
Peru	32	–	4	4	4	4	4	4	4	4
Peruvian	33	2–	3+	1	1–	1	1–	3+	3	1
Plush	1117	–	4	4	4	4	4	4	4	4
Pontiac	1114	–	4	4	4	4	4	4	4	4
Prospect	1140	–	4	4	4	4	4	4	4	4
Psaknon B81	34	–	0	1–	1	;	1–	;	1	1=
Pyramidatum	16	–	2–	2	2+	2+	3–	3	1	1+
Quinn	36	–	1	–	1	1	–	1	–	1
Regal	742	3	3	2	4	4	2+	4	4–	2
(Regal × Manchurian) × (Peatland × Duplex)	68	–	1+	1	1–	0	1–	;	1	–
(Regal × Manchurian) × (Peatland × Duplex)	69	–	0	0	0	0	2	0	1+	1
(Regal × Manchurian) × (Peatland × Duplex)	70	–	1–	0	0	0	1	0	1–	1
(Regal × Manchurian) × (Peatland × Duplex)	71	–	0	0	0	0	1–	0	1=	;
(Regal × Manchurian) × (Peatland × Duplex)	72	–	1=	0	0	1–	1	0	1–	;
(Regal × Manchurian) × (Peatland × Duplex)	73	–	0	0	0	1–	1	0	1	1
(Regal × Mensury) × (Peatland × Duplex)	82	–	0	0	0	0	1+	0	1	;
Sacramento	744	–	2	2	2+	3	2	2	2+	1+
Sandrel	745	–	4	4	3+	4	4	4	4	4
Silver King	1048	4–	4	4	4	4	4	4	4	4
Star	748	4	4	4	4	4	4	4	4	4
Stavropol	749	4	4	4	4	4	4	4	4	4
Stella	750	4	4	4	4	4	4	4	4	4
Stephan × Galore	(Guelph)	–	;	;	0	;	;	1=	;	4–
(Stephan × Galore) × O.A.C. 21	(Guelph)	–	;	;	;	;	;	;	;	4
Success	783	4	4	3+	4	4	4	4	4	4

TABLE VI—*Continued*

INFECTION TYPES ON 246 BARLEY VARIETIES AND STRAINS INOCULATED IN THE SEEDLING STAGE WITH NINE PHYSIOLOGIC RACES OF *Erysiphe graminis Hordei*—*Continued*

Variety or strain	C.A. No.	Infection types with physiologic races								
		1	3	4	6	8	9	10	11	12
Hordeum vulgare—Continued										
Telli	751	4	4	4	4	4	4−	4	4	−
Texan	1173	−	4−	4−	4−	4	3	3+	2+	1+
Titan	1118	−	1−	2+	2	1−	3+	3	4	2
Trebi	753	4	4	4	4	4	4	4	4	4
Tregal	1150	−	4	4	4	4	4	4	4	4
Trifurcatum	891	2	4	4	1+	4	1	1+	2+	2−
Vaughn	759	3+	4	4	4	4	4	4	3	2+
Velvet	755	4	4	4	4	4	4	4	3+	4
Velvet	1133	−	2+	4	3+	2+	4	4	3	−
(Velvet × Olli) × (Peatland × Duplex)	74	−	;	1−	1	;	1+	0	1	1
(Velvet × Olli) (Peatland × Duplex)	75	−	0	0	0	1−	1	0	1−	;
(Velvet × Olli) × (Peatland × Duplex)	76	−	1=	;	0	1−	1−	;	1=	1
(Velvet × Olli) × (Peatland × Duplex)	77	−	0	0	0	1	1	0	1−	1
(Velvet × Olli) × (Peatland × Duplex)	78	−	1−	1+	;	1+	1+	1	1−	1−
Velvon	1151	−	4	4	4	4	4	4	4	4
Virginia Hooded	39	−	3+	4	4	4	4	4	4	4
Warrior	1144	−	4	4−	4	4	4	4−	4	4
White Gatami	40	−	1−	1+	2	1−	1+	1	1+	1
White Hull-less	785	1+	4	4	1	3+	1	1	4	1
Wisconsin Sel.	42	4	4	4	4	4	4	4	4	4
Wisconsin 38	1101	4	4	4	4	4−	3+	4	4	4
Hordeum distichon										
Alpha	801	4	4	4	4−	4	4	4	−	4
Angustispicatum	900	2	1	1+	2+	2+	1	2	1	1+
Archer	88	−	4	4	3	4	4	4	−	4
Archer Goldthorpe	1003	4	4	4	4	4	4	4	4	4
Austrian Hanna St. 66	46	−	4	1	1+	2+	1+	4−	1	1
Baku	870	2	4	3−	3+	4	3	2+	2	2
Canadian Thorpe	816	−	4	4	4	4	4	4	4	4
Charlottetown 80	1100	3	4	4	4	4	4	4	4	4
Chevalier	83	3−	4	4	4	4	4	4	4	4
Clifford	825	4	4	4	4	4	4	4	−	4
Danish Island	1002	3+	4	4	4	4	4	4	3	4
Duckbill	826	4	4	4	4	4	4	4	4	4
Frankonia	1017	2	3+	1+	2+	1+	1	4	1+	1
French Chevalier	822	4	4	4	4	4	4	4	4	4
Foreign 127	48	−	3−	1+	2+	3	1+	4	2	1+
German Brewing	1008	4	4	4	4	3+	4−	4	4	2+
Gold	829	4	4	4	4	4	4	4	4	3
Golden Drop	49	4−	4	4	4	4	4	4	4	4
Golden Pheasant	830	4	4	4	4	4	4	4	4	4
Goldfoil	50	;	0	1−	0	0	;	0	0	4
Gordon	833	4	4	4	4	4	4	4	4	4
Halikon	52	1+	3−	1+	1+	1+	1	2+	1	1−
Halikon	834	1	4−	1+	1+	4	1+	3−	1+	1+
Hanna P3	53	4	4	4	4	4	4	4	4	4−
Hanna	63	−	0	0	;	0	0	0	0	4
Hanna	64	−	4	4	4	4	4	4	4	2+

TABLE VI—*Continued*

INFECTION TYPES ON 246 BARLEY VARIETIES AND STRAINS INOCULATED IN THE SEEDLING STAGE WITH NINE PHYSIOLOGIC RACES OF *Erysiphe graminis Hordei*—*Continued*

Variety or strain	C.A. No.	Infection types with physiologic races								
		1	3	4	6	8	9	10	11	12
Hordeum distichon—Concluded										
Hannchen	837	4	4	4	4	4	4	4	3+	2+
Heil's Hanna 3	61	–	4	4	4	4	4	4	4	4
Horn	1078	4–	4	4	4	4	4	4	4	4
Italy	54	2+	1+	3–	3	4	3–	2+	2+	2
Michigan 2-row	55	4	4	4	4	4	4	4	4	4
Nigrilaxum	788	2+	3+	2+	1+	2+	2	2+	2	2–
Nigrinudum	787	2–	1	1	1	1–	1	1	1–	2–
Nigrum	21	3	0	;	1	4	4	1	2+	4
Nudum	22	2+	2+	1+	2+	2	2+	2+	2	2–
Nutans	23	–	3+	1+	3–	2–	1+	4	1+	1=
Nutans A	24	–	4	4	4	4	4	4	3+	4
Nutans K	25	–	4	4	4	4	4	4	4	4
Orel	852	–	4	4	4	4	4	4	4	4
Orel	14	1+	1=	1	1=	2	1+	1	2–	1+
Plumage Archer	1004	4	4	4	4	4	4	4	4	4
Polish	56	4	4	4–	4	4	4–	4	4	1
Princess	57	4–	4	4	4	4	4	4	4	4
Prussian	58	1+	4–	2	3–	2+	1+	4	2+	1
Rex	1113	–	4	4	4	4	4	4	4	4
Rimpaui	786	2+	1+	2+	3	3	2	2+	1	2+
Sanalta	1088	–	4	4	4	4	4	4	4	4
Scotch Standwell	1007	4–	4	4	4	4	4	4	4	4
Smyrna	859	4	4	4	4	4	4	4	–	4
Smyrna	1052	–	3+	4	3+	4	4	4	4	4
Spartan	860	4	4	3+	4–	4	4	4	–	4
Steigum	862	–	4	4	4	4	4	4	4	4
Stephan	1142	–	;	;	;	;	;	0	;	4
Svalof	59	4	4	4	4	4	4	4	4	2
Svalof Victory	868	4	4	4	4	4	4	4	4	2
Svanhals	864	4	4	4	4	4	4	4	–	4
Svansota	865	4	4	4	4	4	4–	4	–	4
Wheeler's Thorpe	60	4	3+	4	4	4	4	4	3	4
Hordeum deficiens										
Blackhull	813	2	4	1	1	1+	1=	3+	1	1+
Decorticatum	881	2	1	1	3–	1+	1	2+	1–	1
Deficiens	880	3	4	4–	4	4–	3–	4	1+	3–
Foreign 82B	62	–	2–	2–	2	2+	1+	2	1	1–
Steudelli	789	1+	1+	1+	1	1	1	1+	1	1+
Triceros	790	4	4	4	4	4	4–	4	3	3
Tridax	791	2	2	1+	2	2+	1+	2	1	2–
Hordeum intermedium										
Cornutum	897	2	4	4–	2	3	2–	2	2+	1+
Mortoni	894	3	1	1–	2–	3	1+	4	2	2
Nudihaxtoni	895	2+	4	4	4	4	4	4	3	4
Nudimortoni	896	4–	4	4	4	4	4	4	4	4

TABLE VI—*Concluded*

INFECTION TYPES ON 246 BARLEY VARIETIES AND STRAINS INOCULATED IN THE SEEDLING STAGE WITH NINE PHYSIOLOGIC RACES OF *Erysiphe graminis Hordei*—*Concluded*

Name and description[1]		C.I. No.	Infection types with physiologic races							
			3	4	6	8	9	10	11	12
Beldi		190	4	4	4	4	4	4	4	4
Coast		276	2−	3−	1+	1+	3−	1	1+	1−
Coast		510	4	4	4	4	4	4	−	4
Himalaya		620	2	1	1	1	1−	4−	3	1
Hooded Spring	H	716	4	4	4	4	4	4	4	4
Oderbrucker		957	4	4	4	4	4	4	4	4
Luth		972	2	1−	0	1+	1	3	1	1−
Kwan		1016	3+	2	;	;	1+	1=	1	1−
Abacus		1088	3	2+	1−	;	1	1−	1+	1
	H	1347	4	4	4	4	4	4	−	4
Abyssinia		2192	4	;	1−	1+	1−	4	1−	1=
Purple Nepal	PHN	2242	4	4	1−	4	3	1	4	1−
Arequipa		2329	3−	1−	1	2+	1	4	1+	1=
Callas		2440	4	4	4	4	4	4	4	4
Modia		2483	;	;	0	;	;	;	0	0
		2538	1+	2+	3	2	3−	1	3	2−
		2542	4	4	4	3+	4	4	3+	2+
		2549	3	4	4	2+	4	1+	3+	2+
Carre 26		3386	1+	;	;	;	1=	1=	1	;
Carre 180		3390	2+	3	3	3+	4	2+	3	2
Batna		3391	4	1	1=	1=	1−	4	1	1−
Mianwali		3400	0	0	0	0	;	;	0	0
Palmella Blue	2SS	3609	0	;	0	0	;	;	0	1−
		3737	2+	1−	;	;	1−	1=	1−	1−
Sahara		3770	4	2	2	2	2−	4	2	2
Morocco		3902.1	1+	;	0	0	1−	2	1=	;
		4156.2	0	0	0	1+	4	0	3+	2−
		4160.1	;	1=	0	;	1+	;	1+	1
	2	4219	0	;	;	;	;	0	0	;
	2	4220.1	0	;	;	0	;	0	0	1=
		4223.2	1	2	2	1+	2−	1	1	2−
		4356	0	1−	1=	;	1=	;	0	1
		4974	0	0	0	0	0	1=	0	1=
		4975	1+	1−	0	;	1	2−	1−	;
		4979	0	0	0	0	0	0	0	0
Paso	S	5047	2+	2−	2+	2	3	2	2	2
		5326	4−	4	;	4	2+	1=	4	1−
	SS	5366	4	4	1=	4	1	1	4	1
		5644	0	;	0	0	1	0	0	1=
		5647	0	0	0	;	1+	;	0	;
	2	5862	0	;	0	0	;	;	0	;
	2	5863	0	;	0	0	;	;	0	;
Peruvian Sel. 1		5912	1	;	0	0	1−	1	0	1=
		6015	;	1	;	;	1−	1=	;	1=
Cebada Capa		6193	1=	1=	0	0	;	1	1−	1=
		6306	0	0	0	0	;	0	0	0
Morocco		6311	1+	;	0	0	;	1	0	;
Peruvian Sel. 19		6568	1	1−	0	0	1−	1	0	1−

[1] *All varieties are* Hordeum vulgare, *rough-awned, white or blue, with adhering lemma and palea, except where otherwise indicated as follows:*

2 = 2-rowed.
H = hooded.
N = naked kernels.
P = purple.
S = smooth awned.
SS = semi-smooth awned.

The races of barley mildew used in the inoculation tests include all the races so far isolated in Canada; those of wheat mildew include two out of the three races isolated in Canada. Two pots of seedlings, with approximately 30 seedlings to a pot, were inoculated with each physiologic race. With some varieties a considerable number of tests had to be made to establish a satisfactory mean, although with the majority a single test only sufficed. In Tables VI and VII only the average of all the reactions of each variety is indicated.

TABLE VII

INFECTION TYPES ON 124 WHEAT VARIETIES AND STRAINS INOCULATED IN THE SEEDLING STAGE WITH TWO PHYSIOLOGIC RACES OF *Erysiphe graminis Tritici*

Variety or strain	Station No.	Infection types with physiologic races	
		4	5
Triticum vulgare			
Apex	R.L. 1342	4	3
Apex × S-615	Swift Current 4188	4	4
Axminster	R.L. 75	1–	4
Brevit	" 1890	4	3
CAN 1926	" 1948	1	4
Canus	" 1321	4	3–
Carina	" 1889	4	3
Ceres	" 127	4	4
Chinese × Emmer	" 1802	3–	2–
Chinese × Marquis	" 1596	4	3
Chinese × Progress	" 1804	3	4
Chinese × Progress	" 1805	4	1–
Chul	" 543	0	0
Coronation	" 729	1–	0
Democrat	" 1535	4	4
Double Cross	" 2303	3+	4
Double Cross	" 2315	4–	4
D.C. × Ceres	" 625	4	4–
(D.C. × H44) × Marquis	U. Sask. A-31-1	4–	–
(D.C. × H44) × Marquis	U. Sask. A-35-1	4–	–
Early Triumph	R.L. 94	4	4
Eureka	" 1534	4	–
Federation	" 1395	4	4
Fultz	" 1539	4	4
Fultz Sel.	" 1540	4	4
Garnet	" 15	4–	3
Glenwood	" 1411	4	4
Hard Federation	" 1887	4	4
Haynes Blue Stem	" 200	4	3
Hope	" 209	1	0
Hope × Marquis	C-26-86-12	3–	–
Hope × Reliance	R.L. 1110	1–	–
Hope × Reward	" 1165	3–	1–
Hope × Reward	" 1165.2	2–	1–
Hope × Reward	" 1165.3	2–	1–
Hope × Reward	" 1165.4	4–	;
Hope × Reward	" 1165.5	2–	–
Hope × Reward	" 1165.6	3	–
Huron	" 20	4	4
Hussar	" 1892	4–	–
H44-24	" 229	1–	1–
H44-24 × Marquis	" 704.1	1–	1–
H44-24 × Marquis	" 1081	1–	1

TABLE VII—*Continued*

INFECTION TYPES ON 124 WHEAT VARIETIES AND STRAINS INOCULATED IN THE SEEDLING STAGE WITH TWO PHYSIOLOGIC RACES OF *Erysiphe graminis Tritici*—*Continued*

Variety or strain	Station No.	Infection types with physiologic races	
		1	2
Triticum vulgare—Continued			
H44-24 × Reward	" 967	1	1
H44-24 × Reward	" 1097	1	1+
H44-24 × Reward	" 1150	1	2
H44-24 × Thatcher	R.L. 1946	1−	1−
H44-24 × Thatcher	" 1947	1−	0
Illinois No. 1B8	" 1593	3−	4
Kenya	" 1373	4	4
Kenya	" 1374	4	4
Kenya	" 1375	4	4
Kenya	" 1376	4	4
Kenya	" 1377	4	4
Kanred	" 1443	4−	4
Kawvale	" 1451	4	4
Kota	" 571	4	4
K33	" 1885	4	4
Liguleless	" 1936	4−	4
Loros	" 1891	4	4
Malakof	" 1538	4	4
Marquillo	" 132	4	4
Marquis	" 84	4−	4
Ma. × (H44-24-Ma.)	" 1333	1−	0
Ma. × Iumillo	" 1544	4	4
Ma. × Kanred	" 52	4	4−
Ma. × (Pentad × Ma.)	" 1326	4	4
McMurachy	" 1313	4	4−
Mediterranean	" 1537	4	3−
Merit	" 1949	1	0
Minor	" 2058	4	4
NA 95	" 2063	4	3
Norka	" 1888	0	4
Pentad × Marquis	" 986	2+	−
Pentad × Marquis	M.A.C. 12-10-3	4−	−
Pentad × Marquis	M.A.C. 19-19-3	4−	−
Pilot	R.L. 1822	1	1
Prelude	" 25	4	4
Preston	" 207	1	4
Quality	" 133	4	4
Red Bobs	" 1827	4	4
Red Egyptian	" 2061	4	4
Red Fife	" 22	4	4
Redman	" 1834	1+	1−
Red Thatcher	" 1812	4	4
Regent	" 975.1	1	0
Regent	" 975.6	1−	0
Regent	" 975.11	1−	;
Reliance	" 198	3	4
Renfrew	" 135	4	4
Renown	" 716.6	1	2−
Reward	" 79	4	4
Ridit	" 1932	4−	4
Rival	" 1494	4	4
R.L. 625 × Mercury	" 2054	4	4
R.L. 625 × Mercury	" 2055	4	4
R.L. 704 × Marquis	" 1527	2−	1−
Thatcher	" 1945	4	4

TABLE VII—*Concluded*

INFECTION TYPES ON 124 WHEAT VARIETIES AND STRAINS INOCULATED IN THE SEEDLING STAGE WITH TWO PHYSIOLOGIC RACES OF *Erysiphe graminis Tritici*—*Concluded*

Variety or strain	Station No.	Infection types with physiologic races	
		1	2
Triticum vulgare—Concluded			
Thatcher × Regent	" 1829	1	1
Thew	" 1883	0	4
Warden × Hybrid English	" 1803	4	4−
Webster	" 365	4	4
Triticum durum			
Acme	R.L. 566	4−	4
Akrona	" 1252	4	4
Arnautka	" 570	4	4
Belaturka	" 1412	2−	;
Carleton	" 1663	2+	3
Gaza	" 1664	4	4
Golden Ball	" 1256	4	4
Iumillo	" 7	4	4
Iumillo × Mindum	" 1183	4	4
Kubanka	" 565	4	4
Mindum	" 568	4	4
Pelissier	" 145	4	4
Pentad	" 203	4	4
Spelmar	" 569	4	4
Stewart	" 1683	4	4
Tibet	" 1396	4	4
Triticum compactum			
Jenkin	R.L. 1814	4	4
Little Club	" 223	4	4
Triticum dicoccum			
Black Persian	R.L. 388	;	0
Khapli	" 563	;	0
Vernal	" 567	2−	1
Triticum monococcum			
Einkorn	R.L. 227	1−	1−
Triticum timopheevi	" 1308	0	0

Results

The varietal reactions to powdery mildew, as shown in Tables VI and VII, indicate that there is no lack of suitable mildew-resistant breeding material in either barley or wheat. In both of these cereals there exist varieties that are highly resistant to all of the physiologic races of mildew found in Canada. In the case of barley, there are resistant varieties in all but one species tested, *Hordeum intermedium*. In the *vulgare* species, 44 varieties, including 16 Duplex hybrids, are immune or highly resistant to the Canadian races of barley mildew. In *H. distichon* nine, and in *H. deficiens* three varieties possess the same high resistance to all the races. Some of the resistant varieties, such as Duplex (C.A.N. 1129), Psaknon (C.A.N. 34), and Minsturdy

(C.A.N. 732) have also been reported (9, 18) as being resistant to races isolated in the United States but not as yet found in Canada.

Similar results were obtained with wheat. Of the *Triticum vulgare* wheats tested, Chul (R.L. 543), Hope (R.L. 209), H-44-24 (R.L. 229), and most of the varieties and strains derived from crosses having Hope or H-44-24 as one parent, showed very high resistance to the two physiologic races employed in these tests. A variety Kanred (R.L. 1443) was completely susceptible in the seedling stage but acquired moderate resistance in the adult stage (Table V). In *T. durum*, only one variety, Belaturka (R.L. 1412), showed high resistance in the seedling stage to both races, but three other varieties, Gaza (R.L. 1664), Mindum (R.L. 568), and Pentad (R.L. 203), although susceptible in the seedling stage, developed resistance in the adult stage (Table V). The varieties of *T. dicoccum*, *T. monococcum*, and *T. timopheevi* that were tested all proved to be resistant in the seedling stage to the two races.

An interesting feature made evident by Table VI is the fact that all hybrids containing the highly resistant parent, Duplex (C.A.N. 1129), proved very resistant to all the known Canadian races of *E. graminis Hordei*. Apparently resistance in that variety was dominant. Similarly, many wheat hybrids derived from either Hope or H-44-24 were resistant to the two races of *E. graminis Tritici* (Table VII).

It appears, therefore, that it should be possible without great difficulty to combine in these two cereals resistance to powdery mildew with other desirable characters. In fact, the varieties of hard red spring wheat recently developed in Canada, such as Coronation (R.L. 729), Regent (R.L. 975), and Redman (R.L. 1884), are resistant to the presently known Canadian races of *E. graminis Tritici*.

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